Advancing the Understanding of Emissions from Oil and Natural Gas Production Operations

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Overview

PURPOSE: Multi-phase study to understand the capability of different measurement methods and to improve the characterizations of emissions from oil and gas operations.

1. Phase I: Explored measurement approach using ground-based remote sensing technologies for characterizing emissions from enclosed combustion devices (ECD) at upstream oil and natural gas well pads.
2. Phase II: Reviewed data collected from first phase, as well as data from other oil and gas measurement studies, to develop speciated emissions information for oil and natural gas sector.

OUTLINE:

1. Overview of results from Phase I: Measurement of Oil and Natural Gas Well Pad Enclosed Combustor Emissions Using Optical Remote Sensing Technologies
2. Overview of results from Phase II: Total Organic Gases (TOG) Speciation Profiles for Oil and Gas Production Sources
3. Summary

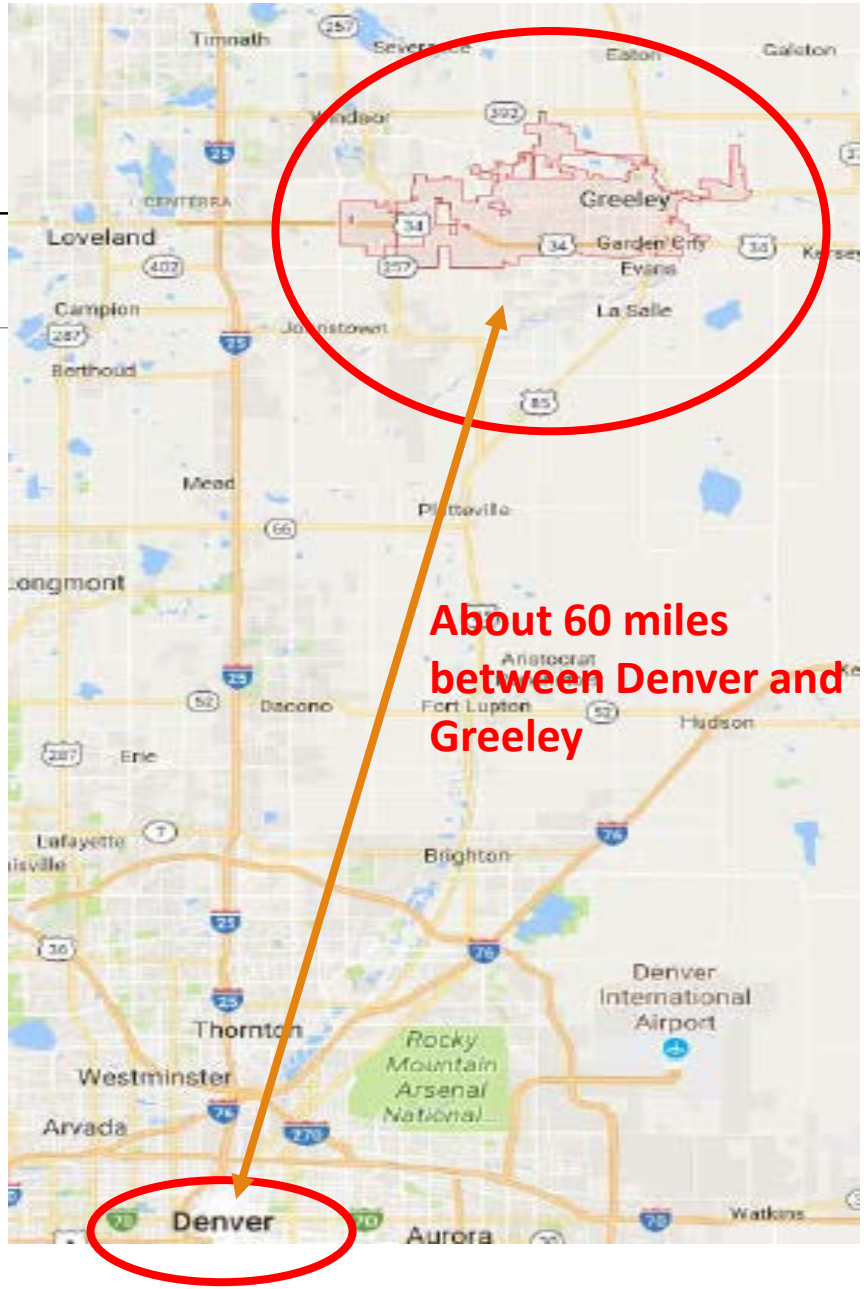
REPORT: Advancing Understanding of Emissions from Oil and Natural Gas Production Operations to Support EPA's Air Quality Modeling of Ozone Nonattainment Areas [EPA #: EPA/600/R-17/224]

Phase I: Measurement of Oil and Natural Gas Well Pad Enclosed Combustor Emissions Using Optical Remote Sensing Technologies

- Enclosed combustion devices (ECD) are commonly used as control devices to control emissions from well pad sources such as storage tanks.
- Previous field studies have shown that methane, VOCs, and hazardous air pollutants can be emitted from improperly maintained or controlled well pads.
- It is important to develop easy-to-use measurement techniques that can be utilized on-site or off-site to assess effectiveness of ECD operations for O&G operations.
- U.S. EPA ORD and EPA Region 8 conducted pilot study to evaluate currently available remote sensing technologies to characterize ECD performance. Goals:
  - Provide speciated emissions information; and
  - Assess combustion efficiency of ECD.

BACKGROUND

- Conducted in the vicinity of Greeley, Colorado over 5 days in September 2014 (8^{th} – 12^{th}).
- Utilized two remote sensing technologies
- Measurements were collected off-site from public roadways.
- 10 well pad sites were investigated in study.
- Pre-measurement screening surveys conducted at each site using infrared camera.
- Study was not part of any enforcement or compliance activity.



Remote Sensing Technologies

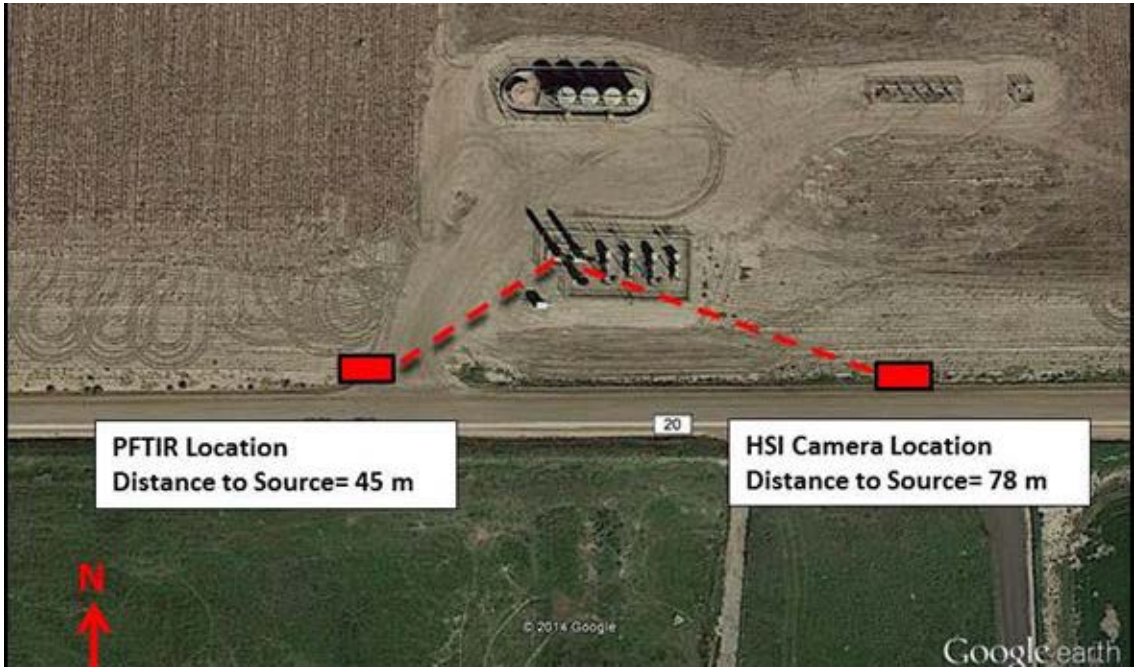
Passive Fourier Transform Infrared Radiometer (FTIR)	Mid-Wave Infrared Hyper-Spectral Imager (HSI)
Analyzes thermal radiation emitted by hot gas in the plume and captured by receiver.	High-resolution spectrum recorder and compares to referenced spectra.
Measures gases present in plume and combustion efficiencies.	Identify and quantify gases present in measured plume.
Instrument deployed from back of trailer.	Mounted to heavy-duty tripod.
Distances of 50 m to 300 m from source.	Distances of 50 m to 300 m from source.

Summary of Collected Data

Site	Date	Time	FTIR (N)	HSI (N)	Number of ECDs at Site (N)	Maximum ECD Temperature Observed (°F)
1	9/8/14	13:00 to 15:05	Emissions from ECD not detected	Not at site	1	246
2	9/8/14	15:31 to 16:10	14	Not at site	2	>155[1]
3	9/9/14	8:00 to 15:16	297	Not at site	4	240
4	9/10/14	10:00 to 17:16	244	578	2	>157[1]
5	9/11/14	9:35 to 12:05	27	488	2	>157[1]
6	9/11/14	12:41 to 13:31	Not at site	110	10	Not available[2]
7	9/11/14	12:15 to 13:50	26	Not at site	4	>157[1]
8	9/11/14	14:25 to 15:17	5	110	4	52
9	9/11/14	16:11 to 16:35	Not at site	55	1	65
10	9/12/14	9:00 to 10:40	Emissions from ECD not detected	Not at site	2	>157[1]

1. ECD temperature data from OGI camera, value shown was the maximum on camera temperature scale during the observations. It is likely that actual ECD temperatures were at times much higher than value presented.
2. Temperature data was not obtainable due to distance from site to measurement location (368 meters).

Site #5: Measurement Configurations



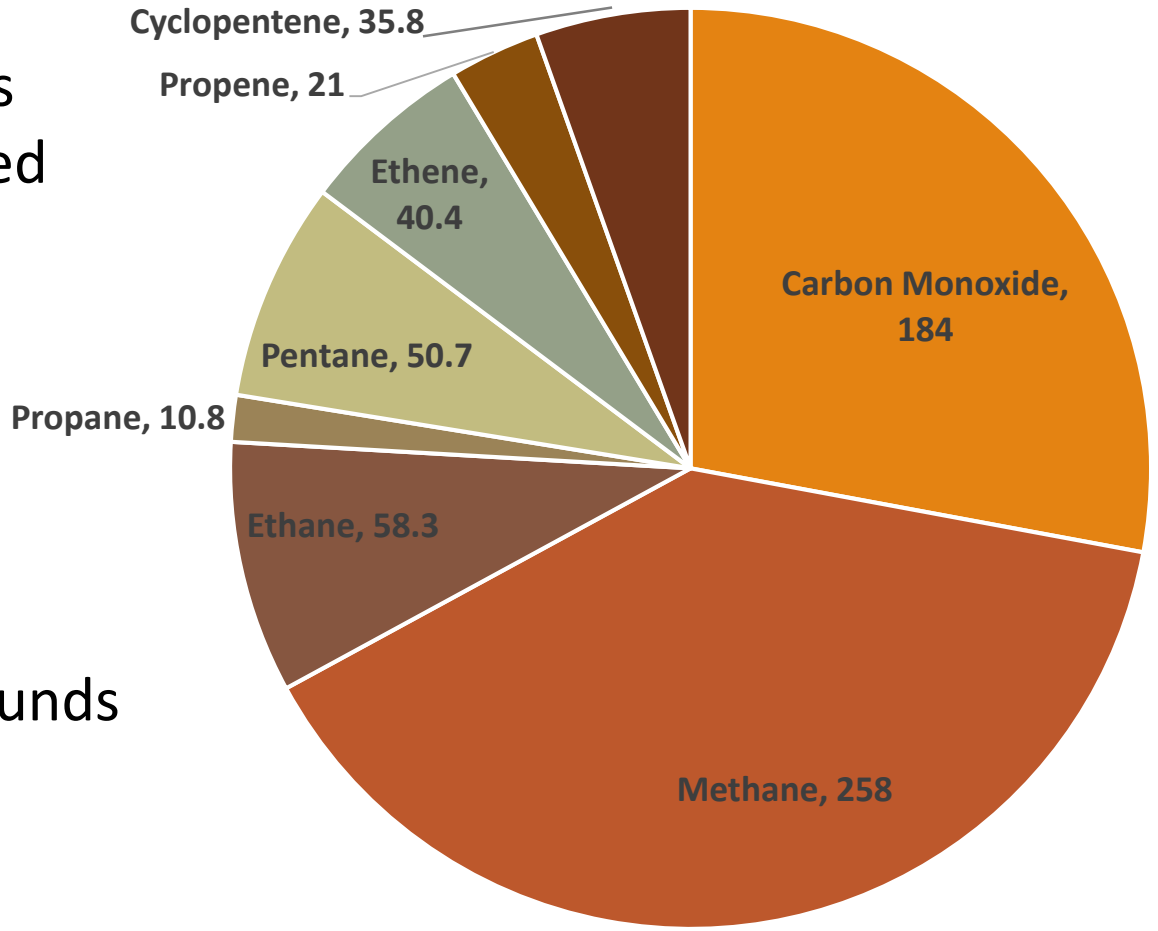
- **Rural and area with dense O&G operations.**
- **Data collected for about 3 hours on September 11, 2014.**
- **Deployed about 60 meters from active ECD stack.**

Site #5: FTIR Path-Integrated Concentrations (ppm-m)

Higher concentrations of alkanes are detected relative to alkenes, including:

- methane,
- ethane, and
- pentane.

Not clear if all compounds were detected by instrument.

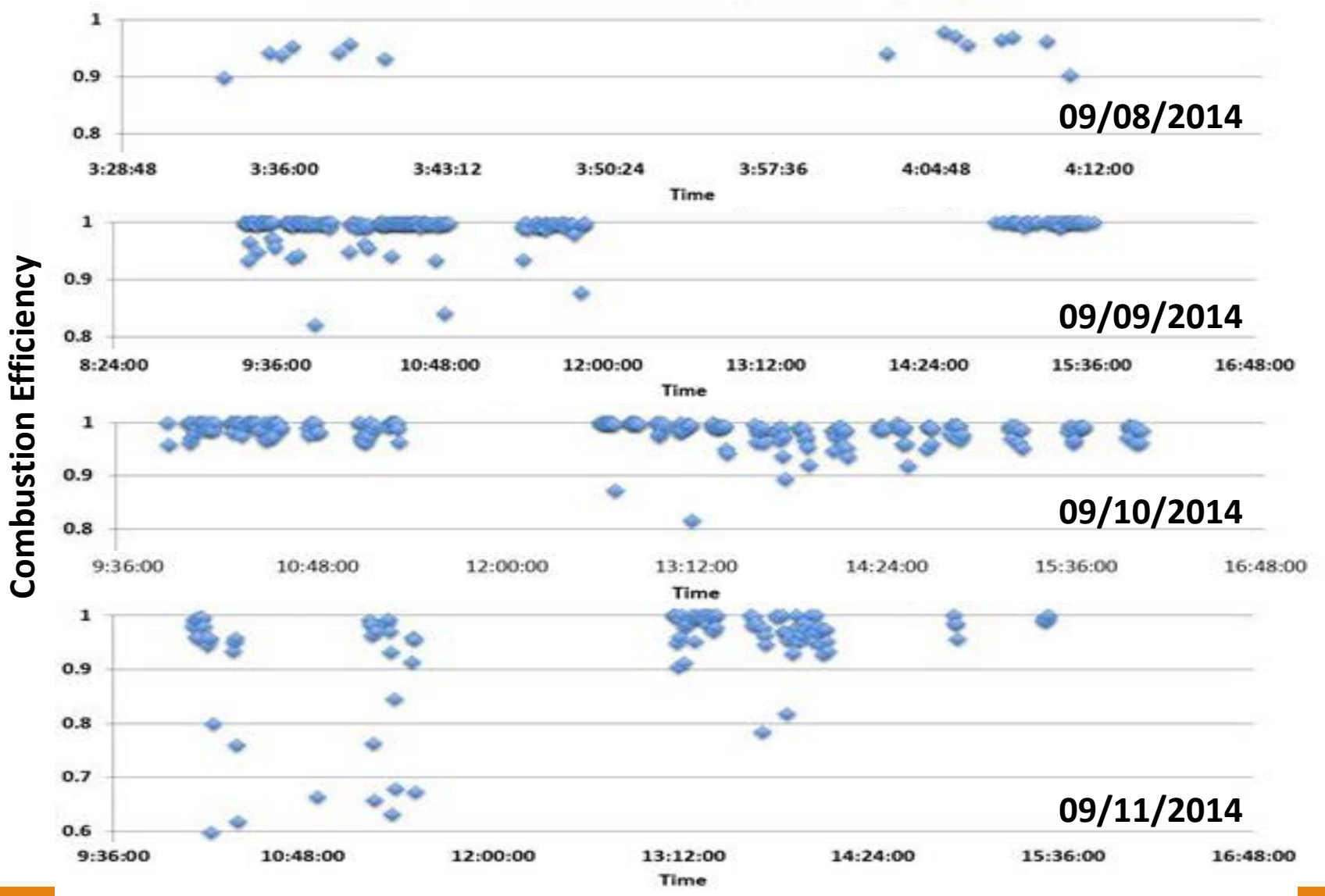


Assessment of Combustion Efficiency

$$CE\ (\%) = \frac{[Carbon\ Dioxide]}{[Carbon\ Monoxide]+[Carbon\ Dioxide]+[Total\ Hydrocarbons]}$$

- Combustion efficiency (CE) defined as the ratio of the mass concentration of carbon dioxide to the sum of the concentrations of carbon monoxide, carbon dioxide, and total hydrocarbons in plume.
- **When the ECD are operating properly, efficient combustion achieved by converting saturated hydrocarbons to carbon dioxide and water. CE greater than 95%.**
- Inefficient combustion occurs when oxygen supply to the ECD is insufficient, forming products of incomplete combustion such as carbon monoxide, hydrocarbons, and carbonyls.
- ECD CE at well pads evaluated using data collected with Passive FTIR.

Site #5: FTIR Daily CE



Site #5: HSI Chemical Map Sequences

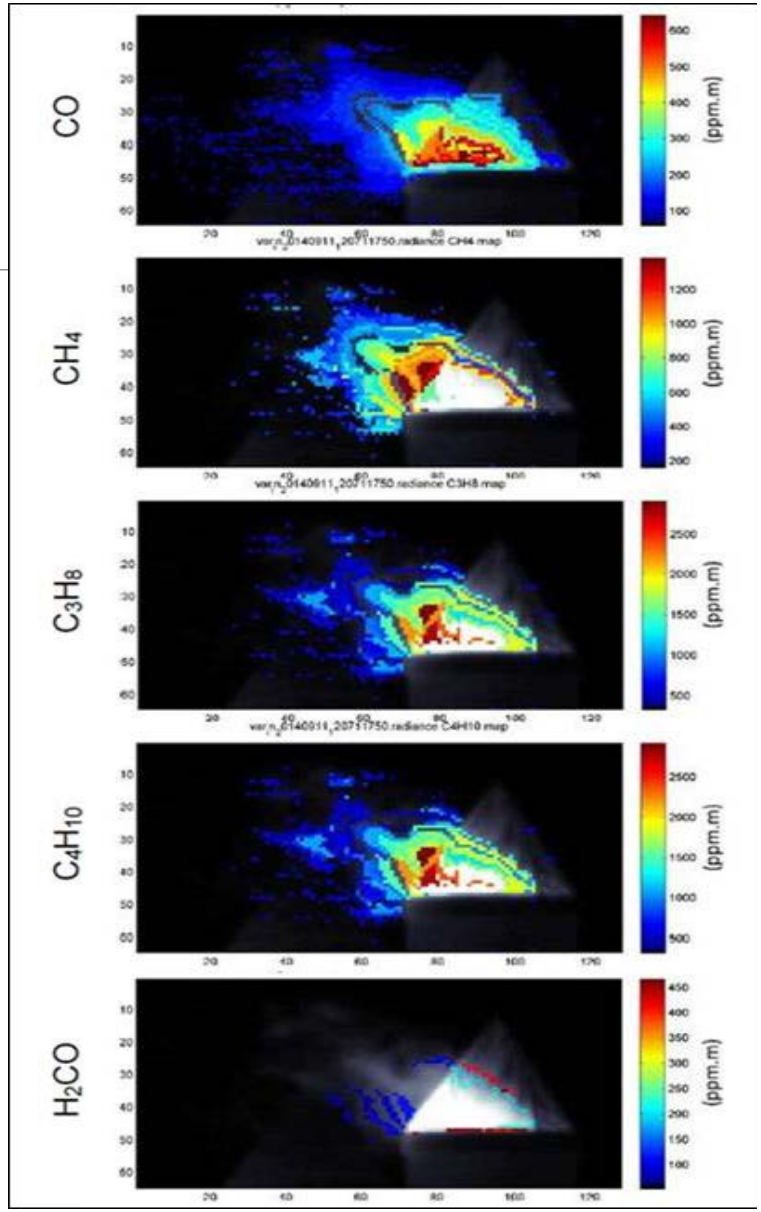
Chemical Map during Burst Stage:

- Carbon Monoxide (CO)
- Methane (CH_4)
- Propane (C_3H_8)
- Butane (C_4H_{10})
- Formaldehyde (H_2CO)

Detected various combustion products and by-products.

Presence of individual gases in combustion gases are diverse and changes rapidly as a function of time.

Difficult to calculate concentrations because of vast number of data points.



Phase II: Total Organic Gases (TOG) Speciation Profiles for Oil and Gas Production

- Speciation profiles important for interpreting ambient measurement data and developing emissions for models.
- Speciation profiles are a critical input to air quality models to convert total emissions from specific sources into speciated emissions. Air quality models are important regulatory tools:
  - Predictions of ozone, NOx, VOCs, and PM.
  - Used to predict air quality impacts and provides foundation for air quality management decisions.
- **GOAL:** Utilize multiple oil and gas measurement studies to evaluate TOG speciation profiles associated with oil and natural gas sector to incorporate into EPA's SPECIATE Database.

Phase II: Total Organic Gases (TOG) Speciation Profiles for Oil and Gas Production (Uncontrolled Sources)

Study	Types of Sources	# of Profiles	# of Species	Range of Methane Contribution [%]	Range of Reactive VOC Contribution [%][1]
RARE ECD Study	Enclosed Combustor Devices	0	0	-	-
WRAP Study	Composite Profiles – Produced Gas for CBM Wells, Non-CBM Gas Wells and Oil Wells; Flashing Gas for Condensate Tanks and Oil Tanks	17	28	0.008-99.9	0.12-36.02
DJ Basin Direct Measurement Study	Individual Profiles of Oil and Natural Gas Production Condensate Tanks; and One Composite Profile	28	58	3.08-28.8	26.1-33.23
Utah Indian Reservations Tribal Minor Source Registrations	Individual Profiles of Oil and Gas Production – Untreated Natural Gas; Oil Tank Vent Gas; Condensate Tank Vent Gas; Glycol Dehydrator; and Four Composite Profiles	41	24	0.02-89.6	1.6-74.13
Texas Study	Composite Profiles of Oil Tank Battery Vent Gas and Condensate Tank Battery Vent Gas	2	33	15.9-37.3	17.42-22.2
California Studies	Composite Profiles of Gas Wells, Oil Wells, Oil and Gas Separators, Oil Well Tanks, Oil Well Casings, Gas and Oil Condensate Wells, and Oil Vapor Recovery Operations	10	59	30.7-96.3	2.3-24.1
Total		98	87[2]		

[1] Represents the sum of benzene, ethane, xylenes (xylene/m&p-xylene/m-xylene/o-xylene/p-xylene), toluene, n-butane, 2,2,4-trimethylpentane, and ethylbenzene.

[2] This number represents the total number of different species among all of the profiles. Because the species overlap among the profiles or not all of the same species are covered in all profiles, this number will not represent of sum of the values in this column.

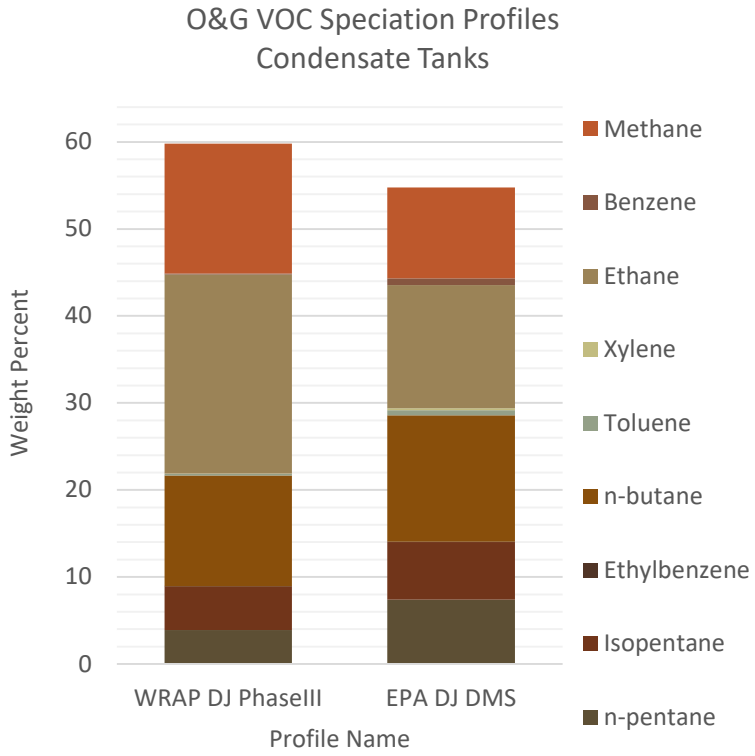
DJ TOG Speciation Profiles: Condensate Tanks

1. **EPA Denver-Julesburg (DJ) Direct Measurement Study (EPA DJ DMS): Condensate Tanks**
   - 27 profiles and 1 composite based on mean of the 27.
   - Based on measured speciated VOCs (GC-FID).
   - Did not measure emissions coming out of enclosed combustor.
   - Halley L. Brantley, Eben D. Thoma & Adam P. Eisele (2015): Assessment of VOC and HAP Emissions from Oil and Natural Gas Well Pads Using Mobile Remote and Onsite Direct Measurements, Journal of the Air & Waste Management Association, DOI: 10.1080/10962247.

2. **WRAP "Phase III" Speciation Profiles (WRAP DJ Phase III): Condensate Tanks**
   - Average of 16 individual profiles.
   - Profiles based on extended gas samples, various test years, emission models (E&P TANKS).
   - WRAP Phase III oil and gas speciation profiles Memorandum, Ramboll ENVIRON, Revised August 27, 2015.

DJ Condensate Tank Comparison

Species	WRAP DJ PhaseIII [Wt%]	EPA DJ DMS [Wt%]	Percent Difference [%]
Methane	14.919	10.439	-43
Benzene	**0.130**	**0.780**	**83**
Ethane	22.855	14.163	-61
Xylene	**0.047**	**0.234**	**80**
Toluene	0.164	0.570	71
n-butane	12.748	14.530	12
Ethylbenzene	**0.004**	**0.023**	**82**
Isopentane	5.043	6.650	24
n-pentane	3.882	7.380	47



Profiles are different and WRAP model-based profiles are slightly more reactive than EPA measured profiles.

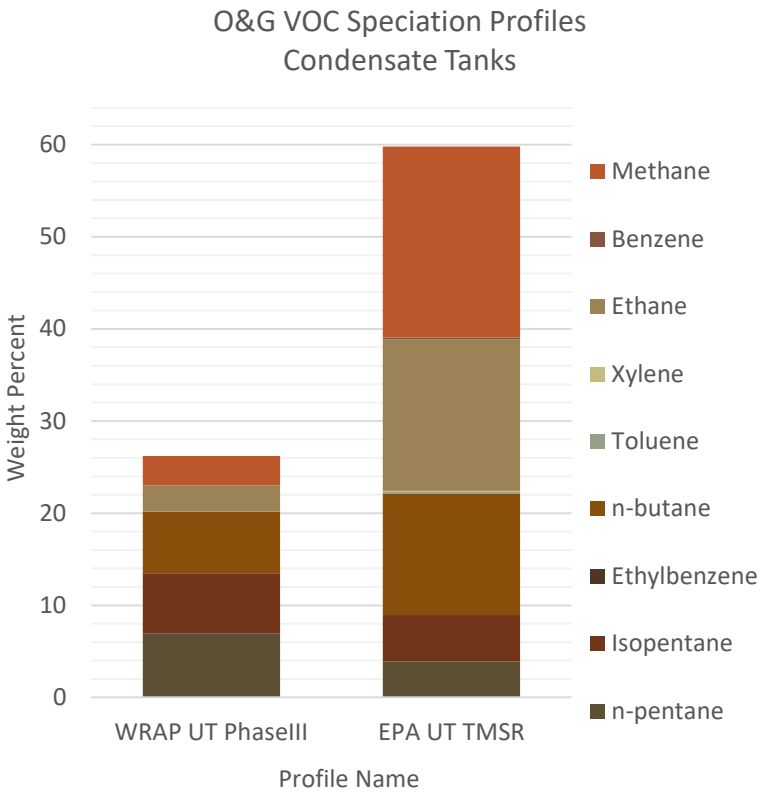
Uinta Basin TOG Speciation Profiles: Multiple Processes

1. **EPA Tribal Minor Source Registration Study (EPA UT TMSR):**
   - Included operator-specific and composite profiles (one composite profile for each process):
     - Raw gas: 15
     - Oil tank: 3
     - Condensate Tank: 11
     - Glycol Dehydrator Regenerator: 4
   - About 5200 registrations surveyed consisting of existing O&G sources (2011 to 2015).
   - Based on lab analyses and emission models (API's E&P TANKS, GOR, GRI-GlyCalc).

2. **WRAP "Phase III" Speciation Profiles (WRAP UT PhaseIII):**
   - Included operator-specific and composite profiles:
     - Produced Gas Composition from CBM Wells: 3
     - Produced Gas Composition from Non-CBM Wells: 28
     - Flash Gas Composition from Oil Tanks: 1
     - Flash Gas Composition from Condensate Tanks: 5
   - Profiles based on extended gas samples, various test years, emission models (E&P TANKS).
   - WRAP Phase III oil and gas speciation profiles Memorandum, Ramboll ENVIRON, Revised August 27, 2015.

Uinta Basin Condensate Tank Comparison

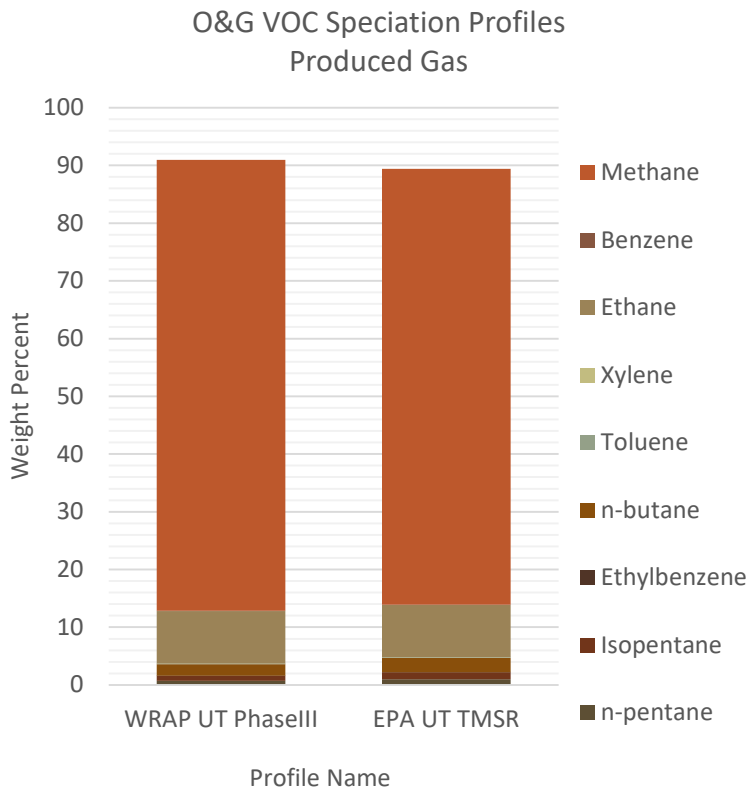
Species	WRAP UT PhaseIII [Wt%]	EPA UT TMSR [Wt%]	Percent Difference [%]
Methane	**3.178**	**20.758**	**85**
Benzene	0.033	0.148	77
Ethane	**2.849**	**16.496**	**83**
Xylene	**0.011**	**0.084**	**87**
Toluene	0.033	0.174	81
n-butane	6.641	13.201	50
Ethylbenzene	0.001	0.004	79
Isopentane	6.506	5.034	-29
n-pentane	6.965	3.908	-78



Profiles are significantly different, and EPA profiles are generally more reactive than WRAP profiles.

Uinta Basin Produced Gas Comparison

Species	WRAP UT PhaseIII [Wt%]	EPA UT TMSR [Wt%]	Percent Difference [%]
Methane	78.112	75.492	-3
Benzene	**0.058**	**0.079**	**27**
Ethane	9.076	9.019	-1
Xylene	0.036	0.032	-12
Toluene	0.083	0.072	-14
n-butane	1.987	2.536	22
Ethylbenzene	0.004	0.004	3
Isopentane	0.885	1.170	24
n-pentane	**0.739**	**1.017**	**27**



EPA profiles slightly different than WRAP profiles.

Summary

- Overview of Phase I: Measurement of O&G Well Pad Enclosed Combustor Emissions Using Remote Sensing Technologies
  - Remote sensing approaches found to be potentially useful for off-site observation of ECD operation if more direct, on-site measurement approaches are not available.
  - Based on FTIR, most ECDs showed relatively high CE (close to or exceeding 0.95).
  - HSI provides ability to identify plume diversity compared to FTIR. However, vast amount of data provided by HSI makes simple determination of CE and concentrations challenging. Requires significant method development work.
  - Limitations:
    - Requires significant set up time and data processing resources.
    - Due to low gas flows/temperatures, difficult to determine whether all targeted compounds were measured.
    - Focused on ambient measurements, as opposed to source-specific measurements.
    - **Source-specific (i.e., condensate tanks, dehydrator vents, pneumatic devices) speciation data are needed for use in speciating VOC emissions.**
- Overview of Phase II: Total Organic Gases (TOG) Speciation Profiles for Oil and Gas Production
  - Reviewed and consolidated about 100 O&G TOG speciation profiles to incorporate into EPA's SPECIATE Database.
  - TOG speciated profiles varied by: oil and gas basin and ratio of the pollutants emitted from the sources/processes.
  - **Care should be taken in selecting speciation profiles to develop speciated emissions for the oil and gas sector**.

Additional investigation is needed before recommending preferred remote sensing technologies for on-site and off-site conditions and speciation profiles for characterizing emissions from the oil and gas sector.